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Effect of Small Aspen Clearcuts on Water Yield and Water Quality

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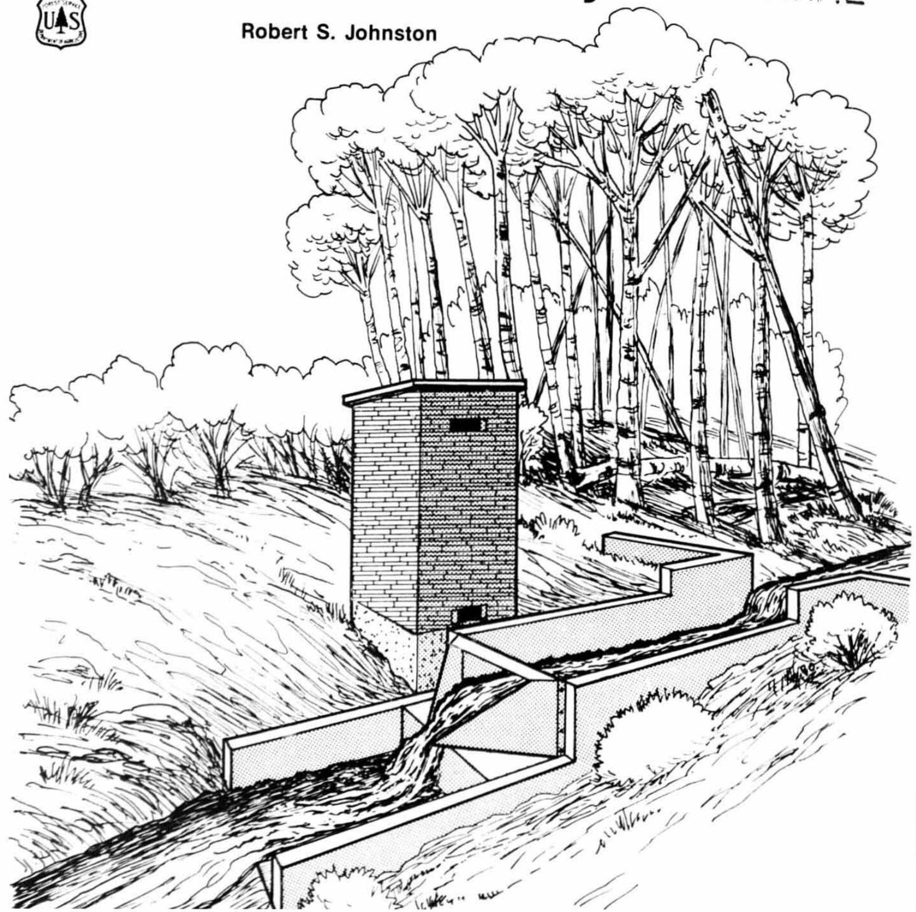

RESEARCH SUMMARY

Streamflow and water quality were monitored in a paired watershed study involving the removal of 20 percent of the aspen (on 13 percent of the area) in five small clearcuts from a 217-acre (88-ha) catchment. There were no significant changes in peak flow, timing, or annual yield during the 4 years of posttreatment monitoring. Significant changes in pH, calcium, magnesium, and nitrates in the snowmelt streamflow from ephemeral subdrainages occurred the second year after cutting. At least some of the differences were attributed to the chemistry of the 1976-77 snowfall, which was also significantly different from snow sampled in the pretreatment period.

ACKNOWLEDGMENT

A major watershed study cannot be conducted over a period of 14 years without the help of many individuals. I am most appreciative to Robert D. Doty, research forester, my co-researcher during most of the study; Ezra Hookano, technician, for his field and laboratory assistances; and Norbert V. DeByle who was project leader and contract officer during the study.

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ROBERT S. JOHNSTON has been a research hydrologist with the Intermountain Station for the past 20 years. He has a B.S. in forestry from Rutgers University and has done graduate work in watershed management and hydrology at Colorado State University. He is currently assigned to the mined-land rehabilitation work unit at Logan, Utah. His major research emphasis has been the hydrologic response of aspen management, rehabilitation of alpine disturbances, and erosion and surface runoff associated with mining.

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INTRODUCTION

It is generally accepted that removing trees from a watershed affects the hydrologic response of the area, usually resulting in increased streamflow. Even though the potential for water augmentation exists, research results have been inconsistent and there remains a question as to whether sufficient increases can be generated through land management to be detectable downstream in larger drainage systems (Office of Technology Assessment 1983).

The measurement of various streamflow parameters and calibration of paired watersheds provide a necessary and logical approach to testing the hydrologic response of given inputs and management alternatives. Classical watershed studies began in the United States in 1909 at Wagon Wheel Gap, CO, and have been conducted since then throughout the United States and many other countries. Hibbert (1967) reviewed the results of 39 catchment experiments and more recently Bosch and Hewlett (1982) summarized the results of 94 catchment studies to determine the effects of vegetation changes on water yield and evapotranspiration. The general conclusion of these reviews was that the removal of forest cover increases water yield, but that results were not consistent regarding the amount of increase, length of the treatment effect, or the effect on streamflow timing or peak flows. Studies have shown that, in general, increases in streamflow are proportional to the amount of timber removed. Other studies have indicated that streamflow response is also related to the type of precipitation (rain or snow) and its distribution through the year, proximity of timber cuts to stream channels, shape of the watershed, drainage patterns, and soil characteristics.

There are about 5,130,000 acres (2 076 000 ha) of aspen (*Populus tremuloides*) forests in Colorado and Utah (Van Hooser and Green 1983; Green and Van Hooser 1983). Most of this forest occurs on federally managed land in the high-water-yielding mountain zone. Whether the managment of aspen can result in increased water yields remains in question. Even if management of forest lands for water production is not feasible or desirable, the hydrologic impacts of aspen management need to be defined.

Results from several plot studies indicated that 3 inches (76 mm) or more of soil water could be saved by removing deeply rooted aspen, thereby eliminating evapotranspiration losses (Croft and Monninger 1953; Johnston 1969, 1970). Based on these results a paired watershed study was initiated in 1965 on the East and West Branches of the Chicken Creek drainage on the Davis County Experimental Watershed. The purpose of this study was to investigate the effects of small aspen clearcuts on the hydrologic response of a small watershed. Because paired watershed studies are very expensive and time demanding, clearcutting only a portion of the aspen acreage was selected as the initial treatment. It was felt that this treatment would be least destructive and would allow a second treatment (total clearcut, grazing, or prescribed burning) to be studied in the future.

SITE DESCRIPTION

A detailed description of the study area was presented by Johnston and Doty (1972). Briefly,the East and West Branches of Chicken Creek are small adjacent catchments, 137 acres (55 ha) and 217 acres (88 ha), respectively, located in the headwaters of Farmington Canyon, about 14 miles (22 km) northeast of Salt Lake City, UT (fig. 1). These drainages lie within the Davis County Experimental Watershed, established in 1930 to study the causes and prevention of erosion and floods originating in the Wasatch Mountains. Elevation of the Chicken Creek catchments is between 7,500 and 8,400 feet (2 286 and 2 560 m). Side slopes are relatively gentle (12 to 45 percent) and each contains gently sloping grassy meadows in the drainage bottom. The area has been protected from fire and grazing since 1930. Both drainages contained small but active beaver colonies throughout the study.

A variety of soils are found on the watersheds, ranging from deep loamy alluvial soils in the bottoms to deep clayey colluvial soils on side slopes and shallow gravelly loams on the ridges. Soils are generally well drained, with good water-holding capacity. Underlying geologic materials are a complex series of igneous outcrops on the ridges, with metamorphic and sedimentary materials on the side slopes and lower portions of the watersheds.

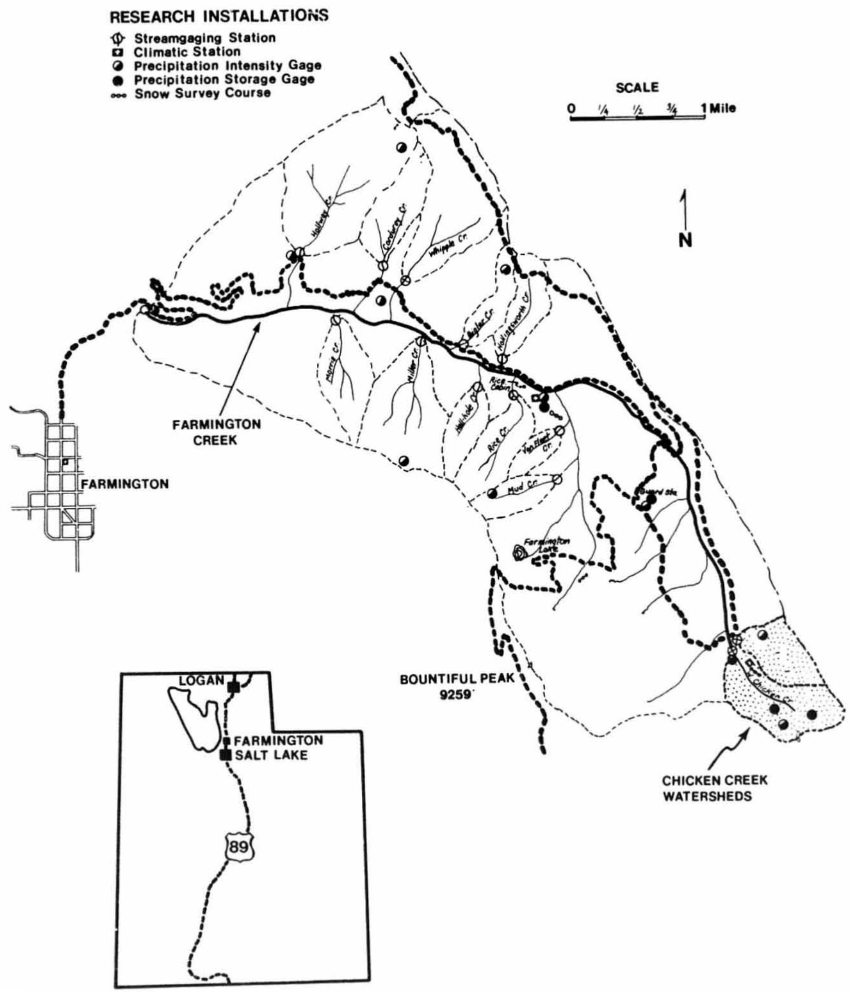

Figure 1.—The Farmington Canyon drainage and Chicken Creek watersheds.

Aspen occupy 63 percent of the East Branch and 66 percent of the West Branch, and they occur throughout the watershed except on the ridgetops and bottom meadows. In 1972, stands had an average age of 32 years, height of 23 feet (7 m), and basal area of 82 ft²/acre (18.8 m²/ha). Many of the aspen clones have a distinct two-story canopy, dominated by a few large trees in the 70- to 80-year-old age class and a large number of smaller trees in the 30- to 40-year-old class. These age classes appear to be closely related to the establishment of the Experimental Watershed and protection from grazing. Protection of this area since the 1930's has contributed to a lush understory vegetation composed of a mixture of grasses, forbs, and shrubs that would not normally be found in areas that are grazed or have been recently burned. Most of the remaining area in the valley bottoms and on the ridges is dominated by grass-forb vegetation, along with scattered areas of mountain brush and sagebrush. A small stand of conifers occurs on each drainage (less than 4 percent of the area). A detailed description of the response of aspen and understory to clearcutting was reported by Bartos and Mueggler (1982).

The climate of this study area is probably representative of large areas of midelevation regions in the Intermountain West. Mean annual temperature was a cool 36.6 °F (2.5 °C) and mean summer temperature (July through September) was 56 °F (14 °C). Average annual precipitation is about 45 inches (1 140 mm), 80 percent of which occurs as snow from November through April. Summers are short and dry and rainfall is highly variable. Most summer rainfall occurs as convective thunderstorms fed by prevailing southwest winds carrying moisture from the Gulf of Mexico. Winter weather patterns are largely dominated by frontal systems moving from the Pacific Northwest, but occasionally winter storms move in from the southwest. Average winter temperatures are below 32 °F (0 °C) with occasional periods of subzero (F) temperatures.

The aspen clearcutting and the large amount of inventory data collected provided an opportunity for several other studies of the impacts of this treatment on water and related resources. These included: vegetation response and dynamics (Bartos and Mueggler 1982), stream temperature (Pettee 1976), impervious watershed areas (Pankey 1980), hydrologic modeling response of aspen-conifer succession (Jaynes 1978), water quality (White 1977), biomass and nutrient content of aspen (Johnston and Bartos 1977; Bartos and Johnston 1978), decomposition and nutrient dynamics of aspen litterfall (Bartos and DeByle 1981), effect of harvesting on songbird populations (DeByle 1981), snowshoe hare-cover relationships (Wolfe and others 1982), and feeding and behavior of mule deer and elk (Collins and Urness 1983).

METHODS

A 3-foot (91.4-cm) H-type flume was installed in 1965 at the mouth of each catchment. Streamflow was recorded with analog-to-digital recorders at 15-minute intervals from April through October and at 30-minute intervals during the remainder of the year. Flumes were covered and heated during the winter months to prevent freezing and provide more accurate discharge measurements (Doty and Johnston 1967).

Air temperature, windspeed, wind direction, and relative humidity were monitored in the West Branch watershed beginning in 1971. The precipitation monitoring network consisted of two shielded storage gauges and a shielded intensity gauge; two additional intensity gauges were operated during summer months. Snowfall was monitored at a snow course on the West Branch. In addition, the precipitation monitoring network was supplemented with over 30 years of record from two storage gauges and two snow courses located in Farmington Canyon.

Clearcut

About 20 percent of the aspen, but only 13 percent of watershed area, were removed in five small clearcuts in the West Branch (fig. 2). The cutting units ranged in size from 3 to 10.2 acres (1.2 to 4.1 ha) and totaled 28.2 acres (11.4 ha). Proposed clearcuts were defined using the following criteria based on the pretreatment inventory: (1) vegetation type was predominantly aspen; (2) deep, loamy, colluvial soils; (3) areas with greatest depth of loosely consolidated subsurface material as identified in the seismic survey.

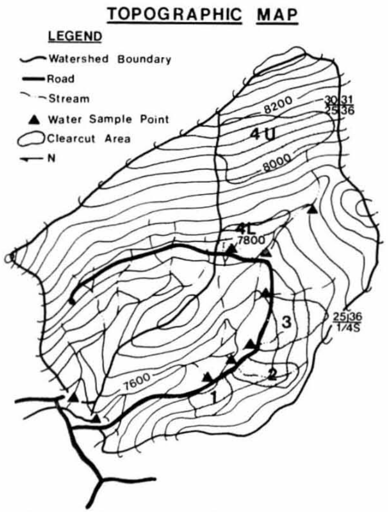

Figure 2.—Topographic map of the East and West Branch watersheds and location of sampling points and clearcut areas.

All aspen greater than 2 inches (5 cm) diameter were cut on all five units. Material suitable for firewood and posts was removed and slash was cut and scattered except unit 4U (fig. 2) where the material was not removed. Most merchantable material was either hand loaded or horse skidded. Vehicle use on the cut areas was minimal. Approximately 62 percent of the area was cut during the summer of 1974 and the remainder in 1975. No access roads were constructed and no work was permitted after the snowmelt season until the area was dry, in order to decrease possibility of surface disturbance and road damage. All cutting was more than 150 yards (137 m) from permanent stream channels.

Water Quality

Water chemistry was monitored at the mouth of each catchment from 1971 through 1976. Water samples were collected at least bimonthly from the beginning of snowmelt until the end of September and monthly during the remainder of the year. In addition, water samples were collected weekly from each of the ephemeral streams draining cutting units 1, 2, and 3 and one uncut drainage adjacent to cutting unit 3. Temperature, pH, and electrical conductivity were measured on site and samples were analyzed for nitrate, phosphorus, potassium, calcium, magnesium, sodium, and bicarbonate using techniques described in "Standard Methods" (American Public Health Association 1971). An automatic event sampler was used to collect samples of rainfall and snow samples were collected at about monthly intervals and analyzed.

Beginning in 1967, bedload and suspended sediment were measured near each flume. Bedload was sampled in a Polyakov-type riverbed sampler installed in each channel. Suspended material was measured from grab samples collected at the flumes.

RESULTS AND DISCUSSION

Water Yield

Mean annual water yield during the calibration period (1966-74 water years) was 136 acre feet (167 754 m³) from the East Branch and 394 acre feet (485 992 m³) from the West Branch. The relationship of annual streamflow from the two areas to each other and to annual precipitation is shown in figure 3. Annual yield is closely related to annual precipitation, which is dominated by snowfall accumulation. About 88 percent of annual flow from both watersheds occurs during the snowmelt period of April, May, and June. Although streamflow from the two drainages is highly correlated, hydrologically the two areas are dissimilar. Analyses of flow records indicate that average water yield from the West Branch was 46 percent of annual precipitation compared to 25 percent yield from the East Branch. Most of this disparity is due to the unequal distribution of snow on the two catchments. For example, a snow-depth contour map of peak snow accumulation during the 1972-73 season showed substantial areas of deep drifting along the southeast boundary of the West Branch and wind scour across the northeast boundary of the East Branch. This distribution pattern indicated about a 30 percent greater snow depth on the West Branch than was calculated from the snow course and storage gauge data, assuming a fairly uniform snowfall distribution.

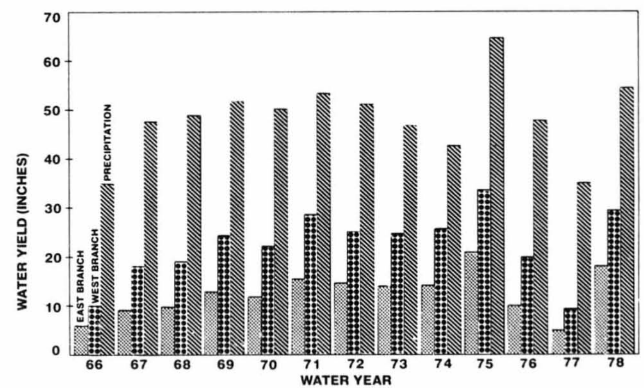

Figure 3.—Comparison of annual streamflow from the East and West Branches of Chicken Creek and annual precipitation.

Streamflow from the West Branch was calibrated against flow from the East Branch for 9 years (1966-74) prior to clearcutting. Annual flows from the two catchments and the regression line are plotted in figure 4. Regression analysis of pretreatment annual flows had an R^2 of 0.97, with a standard error of 1.18 inches (30 mm). Both precipitation and annual streamflow varied greatly during the 4 years of posttreatment monitoring. Annual yield from both watersheds exceeded the maximum and minimum flows previously recorded. These flows were in response to the extreme high and low snowfall amounts in 1975 and 1977, which resulted in the maximum and minimum annual precipitation, 65 and 35 inches (1 650 and 890 mm), respectively (table 1). The predicted yields, using the regression shown in figure 4, were higher than measured yields for 3 of the 4 years after clearcutting; average predicted yield for all 4 years was about 1 inch (2.54 cm) greater than measured. Covariance analysis indicated no significant change in posttreatment total annual flow due to clearcutting ($P=0.05$). Past research has indicated that increases in water yield associated with timber harvest occur either during the peak stream flow period or, more frequently in arid and semiarid areas, during low flow periods. Analysis of peak flows and seasonal flows during both the snowmelt and low flow periods also showed no significant changes after cutting.

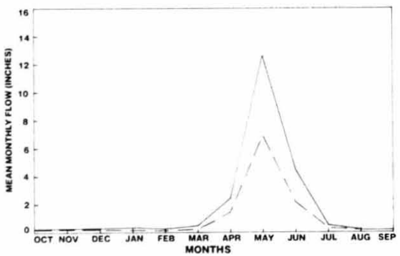

Figure 4.—Relationship of annual streamflow (inches) for the East and West Branch watersheds.

Table 1.—Observed and predicted water yield from the West Branch following clearcutting

Year	Precipitation	Annual yield	Predicted yield	Net change
		Inches		
1975	64.73	33.59	37.29	-3.70
1976	47.64	19.80	18.15	1.65
1977	35.00	9.14	9.38	-.24
1978	54.20	29.66	31.72	-2.06
Average	50.39 (128 cm)	23.05 (58 cm)	24.14 (61 cm)	-1.09 (-3 cm)

Several studies of changes in soil water depletion following removal of deeply rooted aspen (Croft and Monninger 1953; Johnston 1969, 1970) indicated that up to 3 inches (76 mm) of soil water could be saved by reduced transpiration loss. If this water became available as streamflow on the West Branch, the resulting increase in flow would have been about 7 acre feet (8 635 m^3), based on the area cut. This increase was not detected, indicating that linear extrapolation of predicted water increases to area of cut did not apply on Chicken Creek.

Subsequent to this research, recent analyses of results from many watershed studies throughout the United States and other countries have led to the conclusion that removal of less than 20 percent of the forest stand will not result in a detectable increase in water yield (Bosch and Hewlett 1982; Evans and Patric 1983). Results from Chicken Creek, where 13 percent of the watershed area (20 percent of the total aspen area) was clearcut, further confirm this premise. In another Utah study, however, streamflow was increased by up to 4 inches (102 mm) by removing all aspen from a watershed (Robinson 1973). Robinson's results substantiate estimates of potential increases in water yields indicated by the earlier plot studies and show that these increases may be realized when a sufficiently large area is treated.

Average yield from the West Branch during the peak flow period was 13.55 inches (344 mm), nearly twice as great as the East Branch (fig. 5). Flows from both watersheds were very similar during the remaining months. Peak flow during the snowmelt runoff period (April-May) accounts for 86 percent and 88 percent of total runoff for the East and West Branches, respectively. The clearcuts did not appreciably affect snow distribution on the area. The snowmelt rate was observed to be higher in openings than in the adjacent aspen stands, but the change in melt rate for these small areas was not sufficient to cause a detectable shift in the snowmelt hydrograph.

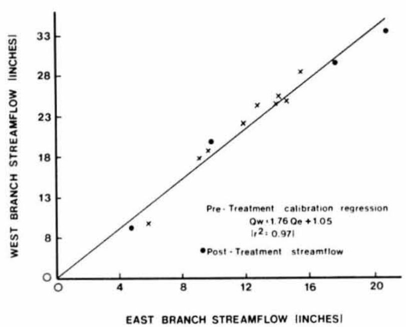

Figure 5.—Distribution of average monthly streamflow prior to clearcutting.

Vegetative Response

The Chicken Creek clearcutting provided an opportunity to investigate the effect of cutting on understory production, community dynamics, and aspen sprouting. Vegetation was inventoried prior to cutting and for 3 years after cutting (Bartos and Mueggler 1982). As expected, clearcutting stimulated aspen sucker production. The average number of suckers increased from 930 per acre (2 300/ha) before cutting to 17,806 per acre (44 000/ha) 2 years after cutting. There also was a significant increase in all understory vegetation following clearcutting, including a general increase in the proportion of shrubs and a decrease in the proportion of forbs. Understory production increased from 900 pounds per acre (1 009 kg/ha) to nearly 2,700 pounds per acre (3 026 kg/ha). It has been suggested that transpiration from these nearly one-half million new aspen suckers and 25.4 tons (23 metric tons) of increased understory biomass may have mitigated some of the water savings realized by cutting the aspen overstory. This response, however, was not noted in the earlier plot studies of soil water depletion following removal of aspen.

Water Quality

The low amounts of both suspended and bedload sediments measured during the pretreatment calibration period indicate good quality water and generally low erosion rates in both watersheds. Average bedload production was only 0.07 and 1.14 pounds per acre per year (0.08 and 1.28 kg/ha) from the West and East Branch, respectively. These materials were primarily sand and gravel, with about 8 percent organic material. Suspended sediment production was also low in both watersheds. The maximum recorded was 135 p/m for the West Branch and 48 p/m for the East Branch, with average suspended sediment of 16 and 6 p/m, respectively. Peak sediment concentration occurred during peak snowmelt runoff and occasionally during rainfall runoff events. Sediment production was influenced by the network of beaver dams in both drainages. These dams and their current state of repair or disrepair respond as either sinks or sources of sediment. Sediment measurements were not continued into the treatment and posttreatment period because it was felt that any treatment effect on sediment production would be masked by the beaver dams. Much of the difference in bedload production between the two drainages is attributed to an abandoned beaver dam above the East Branch gauging station. Also, because of the method of skidding and location of clearcuts away from permanent stream channels, the clearcuts were not expected to contribute significantly to sediment production.

Water Chemistry

Water samples were collected during the spring snowmelt runoff period from ephemeral streams draining cutting units 1, 2, 3, and an uncut control subdrainage located adjacent to unit 3. Samples were collected weekly for 2 years prior to cutting (1973 and 1974) and 2 years after cutting (1975 and 1976). There were significant differences in pH, Ca, Mg, and NO_3 between the pretreatment period and second year following cutting within each drainage (table 2). There were also significant increases in these same parameters from the control drainage, indicating that changes were influenced by factors other than the clearcutting.

Analysis of snow samples collected in April 1976 indicated substantial increases in all four parameters from the previous 3 years' snow samples, suggesting the possibility that changes were due at least in part to differences in precipitation chemistry for that year.

Ionic concentrations from each of the subdrainages were quite different from each other and most were significantly different (95 percent level) from ion concentrations of water samples collected at the mouth of the watershed (White 1977). Diagrammatic illustrations of ion concentration (fig. 6) show that most differences are in the Ca and Mg concentrations, which in turn affect the pH, conductivity, and alkalinity values. Concentrations of Ca and Mg are highest from unit 1 and become progressively lower from subdrainages farther up the watershed. White (1977) attributed these differences to the discontinuity in soil types between the subdrainages. Soils in unit 1 are entirely of shale and siltstone origin; soils in unit 2 are partially shale and siltstone and partially a schistose loam. The remaining subdrainages, unit 3 and the control, which have markedly lower Ca and Mg concentrations, have deep colluvial soils (Johnston and Doty 1972). This relationship was confirmed by White by examining ion concentrations of water soluble extracts from soil columns collected from each of the areas.

Table 2.—Average values of several water chemistry parameters from subdrainages the second year after cutting (b) that were significatly different from precutting values (a)

Parameter		Cut 1	Cut 2	Cut 3	Control
pH	a	7.47	7.49	6.99	6.90
	b	7.93**	7.88**	7.39**	7.11*
Ca mg/L	a		30.78	11.65	14.31
	b		23.01*	8.11**	3.92**
Mg mg/L	a		5.11	2.66	4.43
	b		4.10**	2.09*	1.23*
NO_3 mg/L	a			.04	.06
	b			.11*	.08*

** - Significant at 0.95 percent level or higher
* - Significant at 0.85 - 0.95 level.

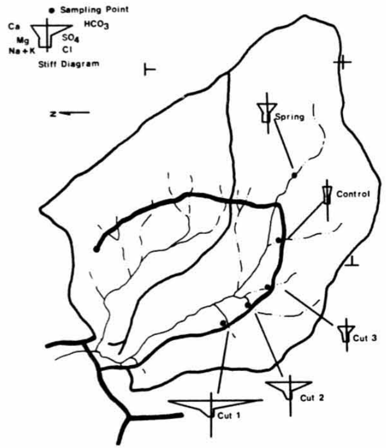

Figure 6.—Variation of major ion concentrations between tributaries in the West Branch watershed, spring 1973 (from White 1977).

Water chemistry from the adjacent East and West Branch watersheds is also quite dissimilar (table 3). In his study, White (1977) concluded:

> The Chicken Creek waters are quite dilute neutral to slightly alkaline solutions containing primarily calcium, magnesium, sodium, potassium, bicarbonate, sulfate, and chloride. Nitrate and phosphate are present at much lower concentrations. The dynamics of the solution are controlled by the $CO_2/CO_3/HCO_3$ equilibrium system. Within the limits of these stated characteristics the waters are extremely variable. The variability can be seen over time and from location to location. The annual chemical budgets indicate that the watersheds are suffering a net loss of all chemical constituents, except nitrate and phosphate . . . . The West Branch watershed not only produces almost twice as much water per unit area, but the water is more chemically concentrated.

Variations in chemistry of these waters are attributed to differences in parent material and soil texture between the subdrainages. Additional causes of variation are the unequal inflow of ions caused by the unequal distribution of snow accumulation on the catchments. Snowmelt water frequently flows overland from rapidly melting snowpacks directly into an ephemeral drainage system and is rapidly delivered to the main stream channel.

As expected, most water quality parameters fluctuated widely throughout the year. Conductivity and pH dropped sharply during peak flows and reached their highest levels during periods of low flows. The highest concentrations of calcium, magnesium, sodium, bicarbonate, and chloride also occurred during low flow periods. Sulfate and potassium concentrations, on the other hand, were highest during the snowmelt period. Nitrate and phosphorus were low throughout the year. Concentrations of potassium, sulfate, chloride, and sodium were highest throughout the year from the East Branch, while the pH, conductivity, and concentrations of carbonate, calcium, and magnesium were highest from the West Branch (table 3).

Table 3.—Comparison of water quality parameters measured between 1971 and 1976 (about 138 samples)

Parameter	East Branch			West Branch		
	Mean	Min.	Max.	Mean	Min.	Max.
pH	7.4	6.4	8.9	7.2	6.4	8.0
Conductivity (μmhos)	158.0	95.0	238.0	119.0	55.0	163.0
Total alkalinity (mg/L)	67.0	32.0	139.0	44.0	16.0	84.0
Calcium (mg/L)	20.7	6.5	36.0	11.3	3.5	32.0
Magnesium (mg/L)	4.2	1.3	8.2	3.5	1.0	9.8
Sodium (mg/L)	6.4	1.8	12.8	7.0	0.7	14.0
Potassium (mg/L)	.9	.1	3.4	.8	.01	4.0
Phosphorus (mg/L)	.1	< .01	.6	.03	.01	.4
Nitrate (mg/L)	.1	< .01	.7	.08	< .01	.4
Sulfate (mg/L)	5.5	< .01	10.7	6.6	< .01	12.0
Total hardness (mg/L)	69.0	30.0	114.0	42.0	12.8	103.0
Chloride (mg/L)	4.8	1.0	12.4	5.0	1.9	9.0

No measurable effects of clearcutting on water chemistry were detected at the mouth of the West Branch watershed. This result is supported by other studies in the Western United States (Sopper 1975; Swanson and Hillman 1977; Fredrickson 1971). Several possible reasons for this lack of chemical response have been suggested. It may reflect the small percentage of area cut and the minimal disturbance during logging, distance of the cuts from main stream channels, deep soils, and possibly low biological activity associated with low annual temperature and low summer precipitation. Although these possibilities are speculative, they are supported by other studies (Brozka and others 1981; Nicholson and others 1982).

Precipitation Chemistry

Chemical analysis of precipitation samples collected between 1972 and 1975 shows considerable variability between storms and between rain and snow events. Both snow and rain tend to be slightly acid, with the 4-year average pH level slightly over 5 (table 4). The pH of individual events varied from 7.7 to a very acid 3.0. In recent years acid rainfall has caused considerable environmental damage and raised concern in the United States, particularly in the Northeast. Acid precipitation also occurs in Utah. One rainfall event at the study site was sufficiently acid (pH 3.0) to destroy the metallic moisture sensing grid on the automatic rainfall collector. Unlike major areas of the Eastern United States, soils in the study area, being generally deep and largely derived from sedimentary material, are capable of buffering acid rain and snowfall.

In general, rain contained higher concentrations of the anions and cations tested than snow. Weather patterns associated with individual storms were not documented during this study. There appears to be a relationship between storm patterns and precipitation chemistry. There are two chemically different types of storms in the area: those with low pH and high NO_3 and SO_4 concentrations and those with high pH and high Ca, Mg, and Na concentrations. This may be explained by the variability of storm patterns that affect the study area. Both winter and summer storms can originate from systems either from the Pacific Northwest or the Southwest. Storms from the Southwest move across the highly populated and industrial Salt Lake Valley before reaching the study area and are presumed to be higher in nitrates and sulfates. Storms approaching from the west and northwest move across vast areas of semidesert and the Great Salt Lake, from which they can pick up and enter large amounts of various salts into the storm system.

CONCLUSION

Removing deeply rooted aspen from 13 percent of a 217-acre (88-ha) watershed had no significant effect on the streamflow timing, peak flow, or annual streamflow yield. Similarly, there were no significant changes in streamflow chemistry attributed to cutting from the catchment or from the ephemeral streams draining the individual cutting units. The lack of measurable effects from harvest may be attributed to the small size of the area cut and the minimal disturbance during cutting. Also, some treatment effects may have been masked by the network of beaver dams in the catchment.

The study does emphasize two important principles: (1) anticipated water yield increases should not be simply extrapolated to the area of harvest and (2) the extrapolation of precipitation measurements, particularly snow, to areal distribution and the subsequent calculation of water yield can lead to serious errors, especially in mountainous terrain.

Table 4.—Comparison of rain and snow chemistry (1972 – 75)

	pH	Conductivity	HCO_3	Ca	Mg	Na	K	P	NO_3	SO_4	Cl
		μmhos	mg/liter								
Rain	5.7*	33	3.80	3.50	0.42	2.07	0.77	0.05	0.43	2.50	1.66
Snow	5.3	12	4.10	1.90	0.23	0.62	0.36	0.02	0.29	1.10	1.07

* Mean values.

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Streamflow and water quality were monitored in a paired watershed study involving the removal of 20 percent of the aspen (on 13 percent of the area) in five small clearcuts from a 217-acre (88-ha) catchment. There were no significant changes in peak flow, timing, or annual yield during the 4 years of posttreatment monitoring. Significant changes in pH, calcium, magnesium, and nitrates in the snowmelt streamflow from ephemeral subdrainages occurred the second year after cutting. At least some of the differences were attributed to the chemistry of the 1976-77 snowfall, which was significantly different from snow sampled in the pretreatment period.

KEYWORDS: hydrology, aspen, *Populus tremuloides*, water yield, water quality

The Intermountain Station, headquartered in Ogden, Utah, is one of eight regional experiment stations charged with providing scientific knowledge to help resource managers meet human needs and protect forest and range ecosystems.

The Intermountain Station includes the States of Montana, Idaho, Utah, Nevada, and western Wyoming. About 231 million acres, or 85 percent, of the land area in the Station territory are classified as forest and rangeland. These lands include grasslands, deserts, shrublands, alpine areas, and well-stocked forests. They supply fiber for forest industries; minerals for energy and industrial development; and water for domestic and industrial consumption. They also provide recreation opportunities for millions of visitors each year.

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